Curriculum Vitae, David Coombs, Ph.D.

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Biography

David Coombs was graduated by Michigan State University in 1986. He received the M.S. and Ph.D. degrees in Computer Science from the University of Rochester in 1988 and 1992; his thesis is titled ``Real-time Gaze Holding in Binocular Robot Vision". (Published in part as David Coombs and Christopher Brown. Real-time binocular smooth pursuit. International Journal of Computer Vision, 11(2):147-164, 1993.) He spent the summer of 1988 in Joe Mundy's group at the General Electric Corporate Research and Development Center studying model-based object recognition. Dr. Coombs began working with the Intelligent Systems Division of the National Institute of Standards and Technology (NIST) in 1991. Dr. Coombs's chief interest is in the role of vision in achieving robust behavior by autonomous and assistive systems. He is applying active vision, peripheral and foveal vision, and multimodal sensorimotor integration to achieve real-time robot mobility and mobile surveillance. He is also developing an intelligent dual-resolution stereo telepresence system and other immersive systems. His interests include building robust systems in challenging environments, human-computer interaction, and the nature of computer use in the future. Dr. Coombs co-organized the AAAI 1994 Spring Symposium on Physical Interaction and Manipulation and he has served as a reviewer of project proposals and books as well as submissions to leading journals and conferences. He is a Behavioral and Brain Sciences (BBS) Associate and a member of the

ACM and IEEE. He was awarded National Merit and Michigan Competitive Scholarships, and has been elected to Tau Beta Pi, Phi Kappa Phi, Pi Mu Epsilon, 2000 Outstanding People of the 20th Century, Who's Who in the World and the Dictionary of International Biography.

Research Goals

Dr. Coombs's primary goal is to advance the capabilities of computer vision to develop autonomous and assistive systems that perform robustly in challenging environments. He is currently engaged in improving autonomous mobility competence in the Demo III Unmanned Ground Vehicle program. He is taking a leading role in understanding user needs, developing algorithms, rapidly prototyping systems, integrating systems, collecting sensor data and evaluating algorithm performance. He is also exploring immersive environments for visualizing data (*e.g.*, from the unmanned ground vehicle) and manufacturing processes and operations (*e.g.*, with the Hexapod machine tool).

For the past several years he has been developing real-time active vision and gaze control of camera movements to aid visual perception. This has enabled a moving robot to keep its cameras smoothly following a nearby moving object. The approach exploits the control of camera movements to simplify the visual processing that is required. The same broad principle has been applied to a robot that uses low-resolution peripheral motion perception to steer between obstacles in a laboratory. The mobile robot rotationally stabilizes its wide-angle camera as it turns. The camera motion approximates forward translation, which simplifies visual interpretation. While potential hazards can be detected with low-resolution vision, some hazards require high-resolution foveal vision to determine their nature and the action that must be taken; combined foveal and peripheral vision is currently being investigated.

Research interests range over computer and biological vision, multimedia communications, real-time systems, robotics, and human-computer interaction. Computer vision interests include active vision, image understanding, and machine vision. Interests in biological vision include computational models, human visual perception, and human factors. Robotics interests center on achieving robust behavior through task-oriented perception, adaptive sensorimotor behavior, and learning in planning and control. Coombs has also developed a prototype foveal-

peripheral stereo-visual telepresence system for teleoperation involving maneuvering and hand-eye coordination of a robot crane.

Education

PH.D.

`Computer Science`, `University of Rochester` (1992). Thesis: “Real-time Gaze Holding in Binocular Robot Vision,” published in part as David Coombs and Christopher Brown. Real-time binocular smooth pursuit. *International Journal of Computer Vision*, 11(2):147-164, 1993.

M.S.

Computer Science, University of Rochester (1988)

B.S. WITH HONOR

`Computer Science`, `Michigan State University` (1986)

Professional Experience

COMPUTER SCIENTIST (1992-PRESENT)

Demo III. Immersadesk. Image flow divergence. Annotated Ground Video (camera calibration).

Intelligent Systems Division (formerly Robot Systems Division), National Institute of Standards and Technology, Gaithersburg, Maryland. We are developing systems for real-time autonomous robot mobility and surveillance on the move. The lure of using motion vision as a fundamental element in the perception of space drives our efforts to use flow features as the sole cues for robot mobility. Low resolution motion vision over large fields of view enables the robot to steer safely between obstacles; active camera control simplifies the motion interpretation. Motion vision also enables the robot to represent its environment for planning efficient mobility. Minimal representations are used to achieve robust vehicle mobility. The use of camera fixation to improve negotiation of a cluttered field is being studied. The Unmanned Ground Vehicle Performance Evaluation Project suggested evaluations of the performance of the UGV. I proposed procedures to evaluate sensing systems for navigation and driving and for steering subsystems. I am coordinating improvement of the laboratory robot platform, including a new robot, camera

motors and a “vestibular system” of angular rate sensors and linear accelerometers. The Robot Crane Project is investigating the use of motorized stereo cameras as a visual telepresence display for crane teleoperation and vehicle driving. I have taken a leading role in developing the division’s presence on the web, installing several of our papers and advertising postdoctoral research opportunities.

SENIOR ENGINEER (ATR), AND GUEST RESEARCHER (NIST) (1991-1992)

Advanced Technology and Research Corporation, Laurel, Maryland, and Robot Systems Division, National Institute of Standards and Technology, Gaithersburg, Maryland. The Sensory Processing and World Modeling Project developed competence in autonomous and cooperative robot applications with a focus on robot mobility. Computer vision provided the robot’s perceptual needs, and deliberate control of the robot’s cameras aided real-time performance in dynamic environments. The empirical laboratory work for this project required the integration of a robot, cameras, and camera motors; real-time image processing used the PIPE.

RESEARCH AND TEACHING ASSISTANT (1986-1991)

Supervisor: Prof. Christopher M. Brown. Department of Computer Science, University of Rochester, Rochester, New York. Teaching: teaching assistant for 2 semesters for graduate courses on compilers and operating systems. Supported, administered and graded class programming projects and lectured in recitations. Research in vision for robots: visual processing and motor control for controlling the gaze of binocular robots. The thesis work focused on holding the robot’s gaze on a moving object while the robot moves (i.e., tracking the object with the robot’s cameras). The approach exploits the control of camera movements to simplify the visual processing that is necessary, enabling real-time performance of the system. The real-time vision processing was performed on Datacube MaxVideo hardware.

RESEARCH INTERN (SUMMER 1988)

Dr. Joseph Mundy, Image Understanding Group, General Electric Corporate Research and Development, Schenectady, New York. Helped install a Pixar and displayed models on it ported from the ImagCalc system. Also worked on using predicted object motion to speed matching a model to a sequence of images.

PROGRAMMER/ ANALYST (1982-1986)

Mr. Laurence Bates, Information Processing, College of Education, Michigan State University, East Lansing, Michigan. Designed and developed software and configured hardware to support office systems in a networked PC environment.

CONSULTANT (JULY 1985)

Client: Prof. Evelyn Oka, Department of CEPSE, College of Education, Michigan State University, East Lansing, Michigan. Designed and developed a system to administer a test of reading comprehension span to children.

PROGRAMMER (SUMMER 1984)

Prof. John Foss, Free Shear Flow Laboratory, Division of Engineering Research, Michigan State University, East Lansing, Michigan. Developed software that identified appropriate regions of data and statistically analyzed those data.

Honors and Awards

NIST Cash-in-a-Flash for excellence in leading data collection, 1997,
NIST Cash-in-a-Flash for excellence in virtual collaboration, 1997,
2000 Outstanding People of the 20th Century,
Who's Who in the World (1998--),
Dictionary of International Biography (1998--),
Who's Who in the East (1997--),
Phi Kappa Phi,
Pi Mu Epsilon (Mathematics),
Tau Beta Pi (Engineering),
Honors College of Michigan State University,
National Science Foundation Graduate Fellowship Honorable Mention,
National Merit Scholarship,
Michigan Competitive Scholarship,
General Electric Information Services Company Scholarship,
Bechtel Power Corporation Scholarship,
Society of Mechanical Engineers Scholarship,
Society of Die-Casting Engineers Scholarship

Professional Activities

CO-ORGANIZER

AAAI 1994 Spring Symposium on Physical Interaction and Manipulation

SESSION CHAIR

ECVNet Active Vision Hardware Workshop 1995,
OSA Topical Meeting on Image Understanding and Machine Vision 1989

REVIEWER

National Science Foundation,
Department of Commerce,
Prentice Hall,
International Journal of Computer Vision,
IEEE Journal of Robotics and Automation,
IEEE Transactions on Pattern Analysis and Machine Intelligence,
IEEE Transactions on Robotics and Automation,
IEEE Computational Science and Engineering,
CVGIP: Image Understanding,
Computer Vision and Image Understanding,
CVPR, IEEE Conference on Computer Vision and Pattern Recognition,
ICRA, International Conference on Robotics and Automation,
OSA Topical Meeting on Image Understanding and Machine Vision

COMMITTEE SERVICE

ISAS 1997 Conference Publications Chair,
University of Rochester Computer Science Admissions Committee 1988,
University of Rochester Computer Science Laboratory Committee 1988

AFFILIATIONS

Behavioral and Brain Sciences Associate,
ACM Member,
IEEE Member

Publications

REFEREED ARTICLES

[1] Theodore Camus, David Coombs, Martin Herman, Tsai-Hong Hong. Real-time Single-workstation Obstacle Avoidance Using Only Wide-field Flow Divergence. *Videre*. accepted for publication pending revision, 1998.

[2] David Coombs, Martin Herman, Tsai-Hong Hong, and Marilyn Nashman. Real-time Obstacle Avoidance Using Central Flow Divergence and Peripheral Flow. *IEEE Transactions on Robotics and Automation*. 14 (1) 49--59. February 1998.

[3] Sandor Szabo, David Coombs, Martin Herman, Ted Camus, and Hongche Liu. A real-time computer vision platform for mobile robot applications. *Journal of Real-time Imaging,* 2(5):315-327, October 1996.

[4] David Coombs. Sensor fusion in motion perception. *Behavioral and Brain Sciences,* 17(2):317-318, June 1994.

[5] David Coombs and Christopher Brown. Real-time binocular smooth pursuit. *International Journal of Computer Vision,* 11(2):147-164, 1993.

[6] Thomas Olson and David Coombs. Real-time vergence control for binocular robots. *International Journal of Computer Vision,* 7(1):67-89, November 1991.

INVITED ARTICLES

[7] Martin Herman, David Coombs, Tsai-Hong Hong, and Marilyn Nashman. Vision-based mobility using optical flow. *Robotics and Machine Perception, SPIE's International Technical Working Group Newsletter,* 3(2):4-5, September 1994.

[8] David Coombs and Steven Whitehead. Report on the AAAI 1994 spring symposium on physical interaction and manipulation. *AI Magazine,* Summer 1994.

[9] David Coombs and Christopher Brown. Cooperative gaze holding in binocular vision. *IEEE Control Systems,* June 1991.

BOOK CHAPTERS

[10] Martin Herman, Marilyn Nashman, Tsai-Hong Hong, Henry Schneiderman, David Coombs, Gin-Shu Young, Dani Raviv, and Albert Wavering. Minimalist vision for navigation. In Yiannis Aloimonos, editor, *Visual Navigation: From Biological Systems to Unmanned Ground Vehicles,* pages 275-316. Lawrence Erlbaum Associates, 1997.

[11] Christopher Brown, David Coombs, and John Soong. Real-time smooth pursuit tracking. In Andrew Blake and Alan Yuille, editors, *Active Vision,* chapter 8, pages 123-136. MIT Press, 1992.

REFEREED CONFERENCE PAPERS

[12] Ted Camus, David Coombs, Martin Herman, and Tsai-Hong Hong. Real-time single-workstation obstacle avoidance using only wide-field flow divergence. In *Proc. of ICPR 1996, the International Conference on Pattern Recognition,* Vienna, Austria, August 1996.

[13] David Coombs, Martin Herman, Tsai-Hong Hong, and Marilyn Nashman. Real-time obstacle avoidance using central flow divergence and peripheral flow. In *Proc. of ICCV 1995, the Fifth International Conference on Computer Vision,* Cambridge, Massachusetts, June, 1995.

[14] David Coombs and Karen Roberts. Centering behavior using peripheral vision. In *Proc. of CVPR'93, the IEEE Conference on Computer Vision and Pattern Recognition,* New York, June 15-17, 1993.

[15] David Coombs and Christopher Brown. Real-time smooth pursuit tracking for a moving binocular head. In *Proc. of CVPR'92, the IEEE Conference on Computer Vision and Pattern Recognition,* Champaign, Illinois, June 15-18, 1992.

INVITED CONFERENCE PAPERS

[16] David Coombs and Karen Roberts. “Bee-bot”: using peripheral optical flow to avoid obstacles. In *Proc. of the SPIE Conf. on Intelligent Robots and Computer Vision XI: Algorithms, Techniques, and Active Vision,* Boston, Massachusetts, November 15-20, 1992.

[17] David Coombs, Ian Horswill, and Peter vonKaenel. Disparity filtering: Proximity detection and segmentation. In *Proc. of the SPIE Conf. on Intelligent Robots and Computer Vision XI: Algorithms, Techniques, and Active Vision,* Boston, Massachusetts, November 15-20, 1992.

[18] David Coombs and Christopher Brown. Intelligent gaze control in binocular vision. In *Proc. of the Fifth IEEE International Symposium on Intelligent Control,* Philadelphia, Pennsylvania, September 1990.

SYMPOSIUM AND WORKSHOP PAPERS

[19] David Coombs. Chairs are no obstacles. In *Working Notes of the AAAI 1994 Spring Symposium on Physical Interaction and Manipulation,* Stanford, California, March 1994.

[20] David Coombs. Exploiting gaze holding for visual following and robot mobility. In *Sigma Xi Postdoctoral Poster Presentation,* NIST chapter, Gaithersburg, Maryland, February 1994.

[21] David Coombs. RoboVac and the cat will get along famously. In *Working Notes of the AAAI 1993 Fall Symposium on Instantiating Real-World Agents,* Raleigh, North Carolina, October 1993.

[22] David Coombs and Christopher Brown. Localized binocular attention and real-time smooth pursuit in moving robots. In *Working Notes of AAAI Symposium on Control of Selective Perception,* Stanford, California, March 25-27, 1992.

[23] David Coombs and Christopher Brown. Real-time gaze holding in binocular robot vision. In *Conference on Spatial Vision in Humans and Robots,* York University, Toronto, Canada, June 1991.

[24] Thomas Olson and David Coombs. Real-time vergence control for binocular robots. In *Proc. of the DARPA Image Understanding Workshop,* Pittsburgh, Pennsylvania, September 1990.

[25] David Coombs, Thomas Olson, and Christopher Brown. Gaze control and segmentation. In *Proc. of the AAAI-90 Workshop on Qualitative Vision,* Boston, Massachusetts, July 1990.

[26] David Coombs. Tracking objects with eye movements. In *Proc. of the Optical Society of America Topical Meeting on Image Understanding and Machine Vision,* North Falmouth, Cape Cod, Massachusetts, June 1989.

[27] David Coombs. Tracking objects with eye movements. In *Proc. of the Fourth Annual University at Buffalo Graduate Conference on Computer Science,* Buffalo, New York, March 1989.

OTHER REPORTS

[28] David Coombs, Sandor Szabo, Martin Herman. The Annotated Ground Video Data Collection Project. *DARPA Project Report.* National Institute of Standards and Technology. Intelligent Systems Division. `http://isd.cme.nist.gov/proj/ground-video/ground-video.fm.html`. August 1997.

[29] Elena Messina, David Coombs, Tom Kramer, John Michaloski, Fred Proctork, Will Shackleford, Keith Stouffer, Tsung-Ming Tsai. Findings and Recommendations for a Software Development Process. *NISTIR 5989, National Institute of Standards and Technology*, Gaithersburg, MD, March 1997.

[30] David Coombs, Martin Herman, Tsai-Hong Hong, and Marilyn Nashman. Real-time obstacle avoidance using central flow divergence and peripheral flow. *NISTIR 5605, National Institute of Standards and Technology (NIST),* February 1995.

[31] Michael Roche and David Coombs. Intelligent systems division homepage. `http://isd.cme.nist.gov/`.

[32] David Coombs. Visual sensing for navigation and driving. In *Recommendations for Performance Evaluation of Unmanned Ground Vehicle Technologies,* chapter 3, pages 32-50. Available as *NISTIR 5244, National Institute of Standards and Technology (NIST),* August 1993.

[33] David Coombs and Christopher Brown. Real-time smooth pursuit tracking for a moving binocular head. *NISTIR 4826, National Institute of Standards and Technology (NIST),* April 1992.

[34] David Coombs. Real-time gaze holding in binocular robot vision. Ph.D. Thesis. *Technical Report 415, University of Rochester, Department of Computer Science,* Rochester, New York 14627 USA, June 1992.

[35] Peter von Kaenel, Christopher Brown, and David Coombs. Detecting regions of zero disparity in binocular images. *Technical Report 388, University of Rochester, Computer Science Department,* Rochester, New York 14627 USA, August 1991.

[36] Christopher Brown and David Coombs. Notes on control with delay. *Technical Report 387, University of Rochester, Computer Science Department,* Rochester, New York 14627 USA, August 1991.

[37] Thomas Olson and David Coombs. Real-time vergence control for binocular robots. *Technical Report 348, University of Rochester, Computer Science Department,* June 1990.

[38] Dana Ballard, Christopher Brown, David Coombs, and Brian Marsh. Eye movements and computer vision. In *1987-88 Computer Science and Engineering Research Review.* University of Rochester, Computer Science Department, Rochester, New York, September 1987.

[39] David Coombs and Brian Marsh. Rover: A prototype active vision system. *Technical Report 219, University of Rochester, Computer Science Department,* Rochester, New York 14627 USA, July 1987.

Presentations

INVITED WORKSHOP PRESENTATIONS

"Mobility Technology for Demo III" Demo III CTT Mobility White Paper presentation, Demo III Inaugural Workshop, Towson, Maryland, March, 1998.

"What is Active Vision good for?" Invited talk, ECVNet Active Vision Hardware Workshop, Le Sappey, France, February, 1995.

"Lessons from experience with robot heads at Rochester and NIST" Invited talk, ECVNet Active Vision Hardware Workshop, Le Sappey, France, February, 1995.

"Mechanical structure issues in robot head design" Invited talk, ECVNet Active Vision Hardware Workshop, Le Sappey, France, February, 1995.

"Coordinated control of Active Vision systems" Invited talk, ECVNet Active Vision Hardware Workshop, Le Sappey, France, February, 1995.

"Animate Vision at The University of Rochester." Invited talk, Unmanned Ground Vehicle Workshop, Pittsburgh, Pennsylvania, May 1991.

CONFERENCE AND WORKSHOP PRESENTATIONS

"Real-time obstacle avoidance using central flow divergence and peripheral flow." ICCV 1995, the Fifth International Conference on Computer Vision, Cambridge, Massachusetts, June, 1995.

"Chairs are no obstacles." AAAI 1994 Spring Symposium on Physical Interaction and Manipulation, Stanford, California, March 1994.

"Exploiting gaze holding for visual following and robot mobility." Sigma Xi Postdoctoral Poster Presentation. NIST chapter, Gaithersburg, Maryland, February 1994.

"RoboVac and the cat will get along famously." AAAI 1993 Fall Symposium on Instantiating Real-World Agents, Raleigh, North Carolina, October, 1993.

"Centering Behavior Using Peripheral Vision." CVPR'93, the IEEE Conference on Computer Vision and Pattern Recognition, New York, New York, June 1993.

"`Bee-bot' takes the middle of the road." SPIE Conference on Intelligent Robots and Computer Vision XI: Algorithms, Techniques, and Active Vision, Boston, Massachusetts, November 1992.

"Disparity filtering: proximity detection and segmentation." SPIE Conference on Intelligent Robots and Computer Vision XI: Algorithms, Techniques, and Active Vision, Boston, Massachusetts, November 1992.

"Smooth pursuit for binocular robots." CVPR'92, the IEEE Conference on Computer Vision and Pattern Recognition, Champaign, Illinois, June 1992.

"How do eye movements influence vision?" AAAI 1992 Spring Symposium on the Control of Selective Perception, Stanford, California, March 1992.

"Intelligent gaze control in binocular vision." Fifth IEEE International Symposium on Intelligent Control, Philadelphia, Pennsylvania, September 1990.

"Gaze control and segmentation." AAAI-90 Workshop on Qualitative Vision, Boston, Massachusetts, July 1990.

"Gaze control and segmentation." University of Rochester Industrial Affiliates, Rochester, New York, May 1990.

"Tracking objects with eye movements." Optical Society of America Topical Meeting on Image Understanding and Machine Vision, North Falmouth, Cape Cod, Massachusetts, June 1989.

"Tracking objects with eye movements." Fourth Annual University at Buffalo Graduate Conference on Computer Science, Buffalo, New York, March 1989.

INVITED SEMINAR PRESENTATIONS

"Robot Gaze Control and Mobility Using Minimalist Vision." Maryland Robotics Seminar, University of Maryland, College Park, Maryland, October, 1994.

"Robot Gaze Control and Mobility Using Minimalist Vision." Artificial Intelligence Lab Seminar, Massachusetts Institute of Technology, Cambridge, Massachusetts, October, 1994.

"Exploiting Gaze Holding for Visual Following and Robot Mobility." GRASP Lab Seminar, University of Pennsylvania, Philadelphia, Pennsylvania, June, 1994.

"Exploiting Gaze Holding for Visual Following and Robot Mobility." Robotics Seminar, Yale University, New Haven, Connecticut, May, 1994.

"Biologically-inspired Active Vision." Robotics Seminar, Columbia University, New York, New York, February 1994.

"Biologically-inspired Active Vision." Computer Science Seminar, Colorado School of Mines, Golden, Colorado, December 1993.

"Biologically-Inspired Robot Vision." Computer Vision Guest Lecture, The Johns Hopkins University, Baltimore, Maryland, April 1993.

"Real-time gaze holding in binocular robot vision." Computer Science Seminar, University of Rochester, Computer Science Department, December 1991.

"Real-time gaze holding in binocular robot vision." Robotics Seminar, Hughes Research Laboratories, A.I. Center, Malibu, California, June 1991.

"Real-time gaze holding in binocular robot vision." Computer Vision Seminar, David Sarnoff Research Center, Princeton, New Jersey, June 1991.

"Real-time gaze holding in binocular robot vision." Robotics Seminar, Martin-Marietta Corporation Space Systems, Denver, Colorado, June 1991.

"Real-time gaze holding in binocular robot vision." Computer Vision Seminar, NIST, Robot Systems Division, Gaithersburg, Maryland, June 1991.

"Real-time gaze holding in binocular robot vision." Robotics Seminar, The MITRE Corporation, Autonomous Systems Group, McLean, Virginia, June 1991.

"Real-time gaze holding in binocular robot vision." Computer Vision Seminar, Alfred I. duPont Institute, Wilmington, Delaware, May 1991.

"Real-time gaze holding in binocular robot vision." Computer Science Seminar, University of Toronto, Toronto, Canada, May 1991.

"Real-time gaze holding in binocular robot vision." Computer Science Seminar, Michigan State University, East Lansing, Michigan, April 1991.

Advisors

`Christopher Brown`, `Dana Ballard`, `Randal Nelson` (Department of Computer Science, University of Rochester),

W. Michael King (Department of Neurology, University of Mississippi Medical Center; previously at Department of Physiology, University of Rochester)